

Determining Desirable Cursor Control Device Characteristics for NASA Exploration Missions

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ABSTRACT

A test battery was developed for cursor control device evaluation: four tasks were taken from ISO 9241-9, and three from previous studies conducted at NASA. The tasks focused on basic movements such as pointing, clicking, and dragging. Four cursor control devices were evaluated with and without Extravehicular Activity (EVA) gloves to identify desirable cursor control device characteristics for NASA missions: 1) the Kensington Expert Mouse®, 2) the HulaPoint mouse, 3) the Logitech Marble® Mouse, and 4) the Honeywell trackball. Results showed that: 1) the test battery is an efficient tool for differentiating among input devices, 2) gloved operations were about 1 second slower and had at least 15% more errors; 3) devices used with gloves have to be larger, and should allow good hand positioning to counteract the lack of tactile feedback, 4) none of the devices, as designed, were ideal for operation with EVA gloves.

Author Keywords

Cursor control device, gloved operations, ISO 9241-9, NASA.

ACM Classification Keywords

H5.2. User Interfaces: input devices and strategies.

INTRODUCTION

The Orion Crew Exploration Vehicle (CEV) that will travel to the moon and Mars, and all future Exploration vehicles, including human habitats will be highly computerized, thus necessitating an accurate method of interaction with computers. The design of any cursor control device will have to take into consideration a number of factors, including g-forces, vibration, gloved operations, and

performance. In this study, the main objective was not to select any particular device, but to begin identifying design characteristics that will work well for unique Exploration mission environments, particularly gloved operations. All cursor control devices have strengths and weaknesses; some are more appropriate for one type of task and less suitable for others. The approach in this effort was a) to develop a test battery for cursor control device evaluation, b) to collect data on movement times and number of errors for a number of commercially available and proprietary cursor control devices used with and without unpressurized Extravehicular Activity (EVA) gloves, and c) to draw some preliminary conclusions about device characteristics that look promising for use in the spaceflight environment.

TEST BATTERY

Soukoreff and MacKenzie [6] recommend the use of the tasks outlined in ISO 9241-9 [4] for the evaluation of cursor control devices. The ISO standard describes a number of representative tasks to evaluate performance, comfort, and effort in using cursor control devices. These include target acquisition, pursuit tracking, freehand input, and dragging. Between-device comparisons are possible with the ISO standards because the methodology is consistent from one study to the next and thus, performance can be compared to a baseline, such as a traditional optical mouse.

The test battery was developed in Visual Basic. The first four tasks in the test battery were based on ISO 9241-9 [4]: unidirectional pointing, multidirectional pointing, unidirectional dragging, and path following. The fifth task (tracing task) was not incorporated for the testing presented in this paper because it did not strongly map to the types of operations envisioned for Exploration missions; it may be added in the future. Non-ISO tasks that had been used in previous evaluations were also added, including a multi-size and multi-distance pointing task [1], a text selection task [2], and a new task that includes interaction with standard interface elements such as drop-down menus, sliders, and checkboxes. The test battery software captures pointing, tracking or dragging times, as well as the number and types of errors. Furthermore, parameters such as target size, and distance between targets, are adjustable for all tasks.

Test Battery Tasks

The following tasks were included in the test battery (see Figure 3. for screenshots).

Task 1. Unidirectional (horizontal) pointing task. Two rectangles with a width of 16 pixels and a center-to-center distance of 512 pixels were presented to the participants. The task was to click back-and-forth between the two rectangles. Clicks outside of the rectangles were recorded as errors.

Task 2. Multidirectional pointing task. Twenty-five numbered squares, each with a width of 16 pixels were arranged around a circle of a 450 pixels diameter. The task was to point and click on the squares in consecutive order along the diameter of the circle. Clicks outside of the squares were recorded as errors.

Task 3. Unidirectional (horizontal) dragging task. The task was to drag a square from one rectangle to another. The width of the rectangle was 16 pixels and the distance between the two rectangles was 512 pixels. Dropping the square outside of the rectangles was recorded as an error.

Task 4. Unidirectional (horizontal) path following. The task was to drag a square through a long “tunnel” consisting of two lines. If that square touched any of the lines, it was counted as an error and the trial was restarted.

Task 5. Text selection. This task was developed by Gillan and colleagues [2]. The task was to click the Start button, and then move directly to the underlined portion of the displayed text and highlight (drag-select) it. The pointing distance to the text was 128 pixels. The to-be-selected text was in 12 pt Arial font and was 1, 5, 9, or 14 characters long. If the drag selection did not include all underlined characters, or included non-underlined characters, or was dropped, an error was recorded.

Task 6. Multi-size and multi-distance pointing task [1]. The participant was presented with twenty-four consecutively numbered buttons of different sizes (63 to 163 pixels) and at different distances (60 to 180 pixels) from a Start button. The task was to click the Start button and then move directly to a target button in consecutive order by number labels. Clicks outside of the target areas were recorded as errors.

Task 7. Standard interface element tasks. The task was to interact with standard interface elements as instructed in written procedures, including: drop-down menus, sliders, text boxes, radio buttons, and check boxes.

STUDY

Method

Participants

Ten volunteers from NASA Johnson Space Center participated in this study. Five were male and five were female. The average age was 30 years, and all participants

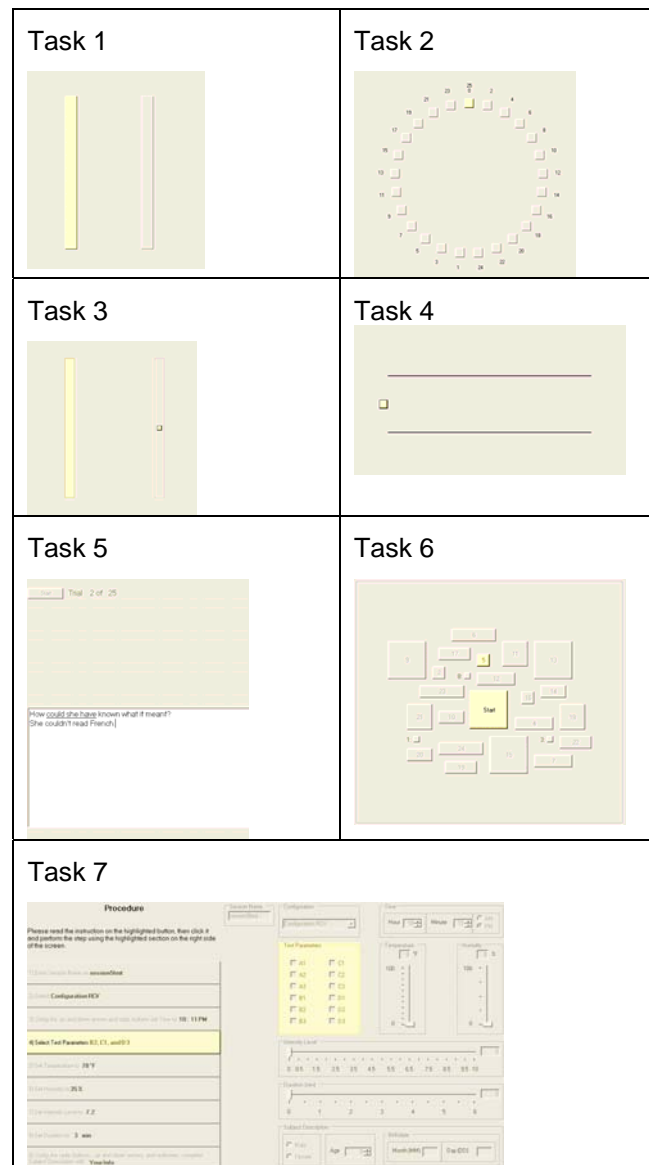


Figure 3. Screenshots of the tasks used in the test battery

were right handed. None of the participants experienced with these devices, although most were familiar with trackballs.

Equipment

The study was run on Windows XP with a screen resolution of 1024 x 768. For all devices, the default settings were used, resulting in differences in gain. This was not a concern for this evaluation, since several studies showed that gain has only a small effect on movements that occur over short distances [5].

The EVA gloves consist of a thin cotton liner, an internal bladder, and an outer covering (thermal micrometeoroid garment-TMG). The TMG has plastic fingertips and a plastic palm patch. All participants used a glove that best fit their hand size: small, medium or large.

The evaluated devices are shown in Figure 1: 1) the Kensington Expert Mouse® (“large trackball”), 2) Hulapoint mouse (“Hulapoint”), 3) Logitech Marble® Mouse (“small trackball”), and 4) Honeywell trackball (“aircraft trackball”). Previous studies have found trackballs to work well in microgravity, so several trackballs were selected for this evaluation [3]. In addition, a recent laboratory study involving eight cursor control devices found that these trackballs in particular had good movement times and small error rates; the Hulapoint was selected for inclusion due to the sturdy design and force activated features.

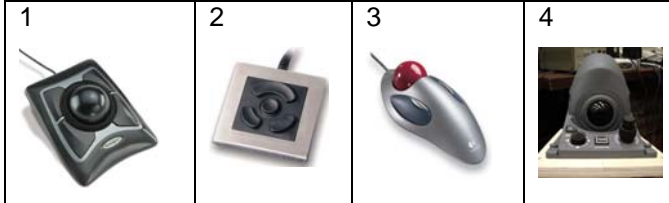


Figure 1. The cursor control devices used in the study: large trackball, Hulapoint, small trackball, and aircraft trackball.



Figure 2. Pictures of the small trackball used without and with gloves.

Procedure

The study consisted of three sessions: one without gloves (four devices) and two sessions with EVA gloves (two devices within each session). The order of the devices and the order of the tasks were randomized in all sessions. For each device and each condition, participants completed a practice session of 30 trials with the unidirectional pointing task to get used to the device. This was followed by the seven tasks in random order, and finally a comfort survey taken from ISO 9241-9 [4].

Movement times were defined as the time between the first click until the final click within a trial, or from picking up an object until dropping it at the target location. Errors were defined as any click outside the target during a trial, the drop of the object, or bumping into the “walls of the tunnel” in the case of the *path following* task.

Results

Movement times and errors

The first 5 trials from each task were considered practice and were excluded from the analysis. Trials with errors were excluded from the movement time analysis. Data were collapsed across task type for the purpose of this publication.

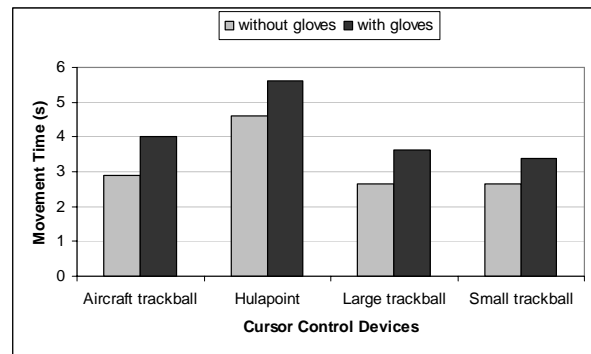


Figure 4. Overall movement times for without and with gloves for the four devices.

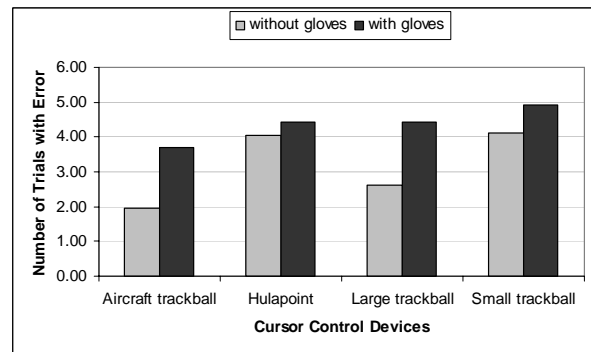


Figure 5. Errors without and with gloves for the four devices.

Overall, movement times were longer for all devices with gloves than without gloves. As shown in Figure 4, the average movement time difference between the gloved and ungloved conditions was about 1 second, and the difference was somewhat smaller for the Hulapoint and the small trackball than for the other two devices. The Device (4) x Glove (2) repeated measures ANOVA found a main effect of device, $F(3,15) = 5.29, p < 0.001$ and a main effect of glove, $F(1, 5) = 90.07, p < 0.001$. There was no interaction ($p > 0.15$). Similarly, accuracy was also reduced by wearing gloves: there were more errors for all devices used with gloves than without gloves (see Figure 5). On average, the difference in errors between the gloved and ungloved conditions was small for the Hulapoint and the small trackball, and larger for the aircraft and large trackballs.

Subjective ratings

Participants rated the devices on several scales that were combined into the following dimensions: ease of use, intuitiveness, and comfort. For ease of use and intuitiveness, most devices were rated higher without gloves than with gloves, except the Hulapoint, which was rated more than two points higher on ease of use with gloves than without gloves. This device required much less effort with gloves than without gloves.

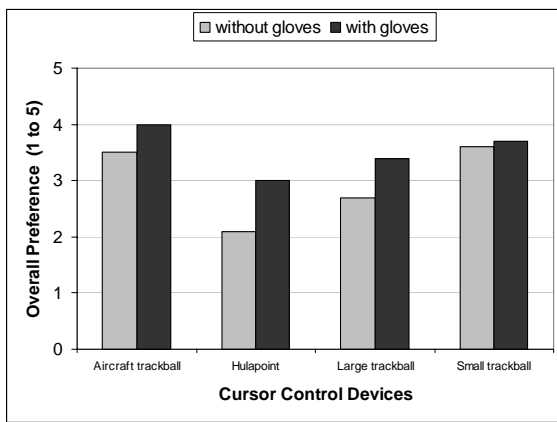


Figure 6. Overall preference ratings as a function of glove and device.

The large trackball and the Hulapoint were rated higher on subjective accuracy with gloves than without gloves. Comfort ratings were also similar for the two conditions. Overall, gloved and ungloved ratings were the same for the other measures and devices (See Figure 6). Participants had less difficulty with gloved movements in the lateral direction and use of the entire hand than when using the individual fingers. Furthermore, bending the fingers was very fatiguing for all participants. This made the drag and drop tasks the most difficult.

DISCUSSION

The EVA gloves reduced tactile feedback considerably, leaving some sensation only on the tip of the fingers. This lack of tactile feedback forced participants to frequently check the position of their fingers on the devices. The size and shape of the devices had a larger effect on comfort when used with gloves than without gloves. For example, the Hulapoint buttons were placed too close to each other. This made dragging particularly difficult. The trackball component of the large and small trackballs proved to be easy to move accidentally, which led to large error rates. Overall, movement times and errors were about 1 second longer in the gloved sessions than in the ungloved sessions, which was expected. The Hulapoint was the slowest of all three devices and had higher error rates as well. The aircraft trackball was slower than the other two trackballs, but its stiff ball made it more accurate than all of the other devices. Obviously, modifications to ball stiffness, cursor gain, and button spacing could be made, and would yield these devices much more usable; however to reiterate, the goal was to identify desirable device characteristics, rather than select a specific device.

CONCLUSIONS

The purpose of this study was a) to develop a test battery based on existing standards and previous studies for cursor control device evaluation and 2) to apply the test battery to evaluate cursor control devices used with EVA gloves to identify desirable cursor control device characteristics for spaceflight environments, particularly for gloved

operations. The test battery proved to be a very useful tool for this endeavor and it will be made public as a NASA product. The package will contain a detailed description of the tasks, the data captured by the application and information on how to use it. The tasks can be used individually or as a full test battery depending on the need: in some situations pointing is the most frequent action; in others text selection and dragging could be common as well. Since unpressurized gloved usage of cursor control devices may be frequent in industrial settings as well as in aviation, these results may be applicable and useful in those domains as well. From the study, the following recommendations were developed for gloved operations:

1. When gloves are used, a cursor control device should be large, the controls/buttons must be spaced out, and the cursor control component should be stiff enough so accidental activation does not occur.
2. Since gloves are heavy, there should be good ergonomic hand and finger support for extended use.
3. The device should allow good hand positioning with easy reference points, so that very little visual feedback is needed.
4. Lateral hand movements rather than grasping movements should be used so the user will not have to move his/her fingers against the resistance of the glove.

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